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Water quality assessment of some selected hand dug wells and a borehole in north western parts of Bauchi Metropolis, Bauchi state, Nigeria

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Abstract
To establish the quality of water meant for human consumption, domestic, livestock and irrigation purposes, water samples were taken from nine different hand dug wells and a borehole in north western part of Bauchi. The samples were analyzed to establish the physical, chemical and microbial characteristics of water. The peak turbidity was recorded in Lafiyari (GW2), while that of temperature was in Tambari (GW6). Wuntin Dada (GW3) show the highest Electrical Conductivity (EC), Total dissolved solids (TDS) and Total hardness which exceeds the highest acceptable limits of NIS. The levels of calcium and magnesium in Wuntin Dada (GW3) and Kyaure (GW5) were higher than the maximum acceptable limits. Total coliform and faecal coliform have their highest values in Kyaure (GW5) and all the values of the ten (10) samples for these parameters are above the maximum permissible limit of NIS. These high values may be due to proximity of the water bodies especially wells to dumpsites, gutters and pit latrines. This may lead to severe water borne diseases.

Keywords: water quality, NIS, Bauchi-Nigeria, standard methods

1. Introduction
The physical and chemical analysis of natural water has high significant impact on public health studies. These studies encompasses environmental pollution [1-5]. In groundwater studies, water quality assessment is one of the most significant aspects. The hydro chemical studies have shown that the quality of portable water including agricultural and industrial purposes [6]. Analysis of chemical parameters of ground water plays a significant role in classifying and assessing water quality. Ground water consists of major, minor and trace dissolved constituents. Constituents with concentration greater than 5 mg/L, 0.01-10.0 mg/L and less than 0.01 mg/L are classified as major, minor and trace respectively [7]. Many literatures revealed the risk of water pollution by heavy metals [8-19].
The objective of this research is aimed at evaluating some of the aforementioned parameters in some hand dug wells and a borehole chosen in the ancient Bauchi, Nigeria, that will cause pollution and in what concentration if present and comparing it with the National Standard for Drinking Water Quality (NSDWQ) of Nigeria Industrial Standard (NIS).

2. Materials and Method
2.1 Study Area
Bauchi is an urban city in Bauchi state, Nigeria. The study area lies between latitudes 10.293139ºN and 10.325556ºN and longitudes 9.751806ºE and 9.78975ºE on a scale of 1:50,000, south west of sheet 149NE Bauchi. The area is generally accessible through a tarred road, an untarred road, minor roads and footpaths that link the various villages/settlements and farms (Figures 1, 2, 3).

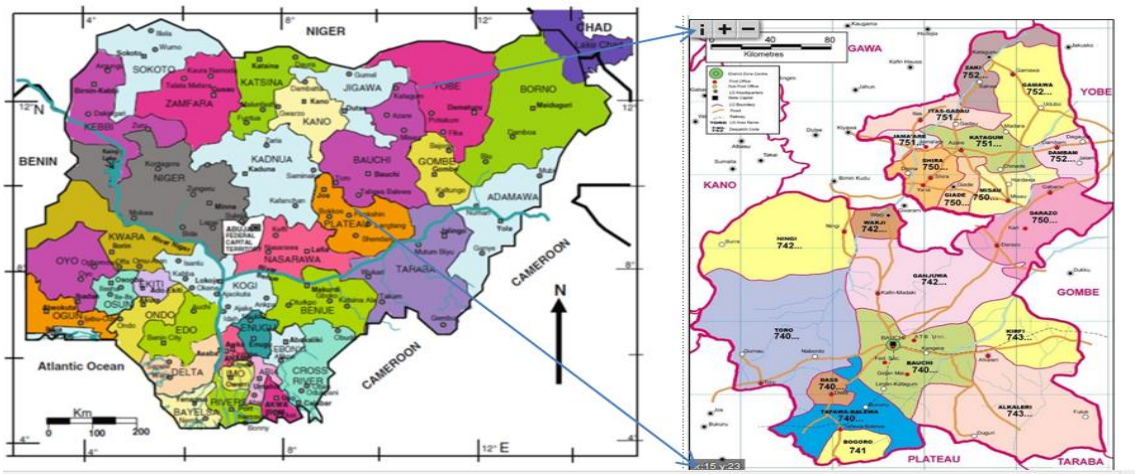

Fig 1: Current federating states of Nigeria (36 in number as at 2008). **Fig 2:** Map of Bauchi State Showing Local Government Areas

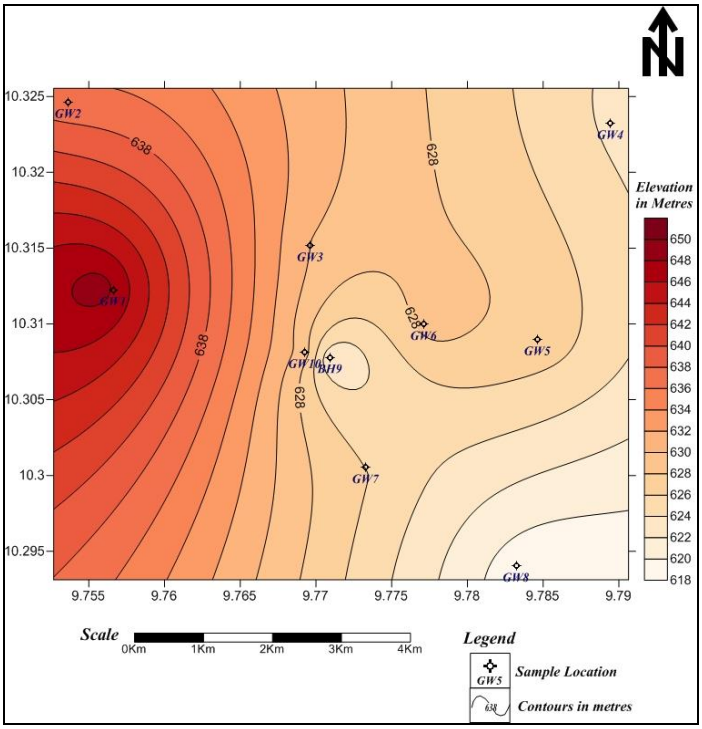

Fig 3: Location Map of Sample Points

Water samples were collected from ten (10) different stations in north western parts of Bauchi metropolis. Sample GW1 was collected from Tsohon Kampani, GW2 from Lafiyari, GW3 from Wuntin Dada, GW4 from Guru, GW5 from Kyaure, GW6 from Bello Kaliel, GW7 from Rafin Tambari, GW8 from Sabon Kaura, BH9 from ATA Polytechnic Bauchi and GW10 from ATA Polytechnic Bauchi. All the samples are from hand dug wells except sample BH9 which was collected from a borehole. The samples were collected in the month of May, 2012. Sample bottles were treated with dilute nitric acid followed by repeated washing with distilled water and with the water source before sampling after which they were transferred to the laboratory for analysis. Coordinates at every sampling point were taken using Garmin Navigator Global Positioning System (GPS). Physical parameters (temperature, electrical conductivity, turbidity and pH) and microbial analysis were determined by standard methods using Potalab WE10016 components and accessories, while chemical analysis for the determination of cations and anions in all the samples was also done by standard methods using DR 2000 Hach Spectrophotometer [20].

3. Results and Discussion

The combined result of physical, chemical and microbiological parameters of analyzed Water samples in parts of Bauchi metropolis and Environs is shown in Table 1. Water Quality assessment for this study is based on the maximum permissible units of the Nigeria Standard for Drinking Water Quality (NSDWQ) of Nigerian Industrial Standard [21]. The temperature values were in the range 27.0-30.0^{o}C [lowest in Lafiyari (GW2) and Kyaure (GW5), highest in Bello Kaliel (GW6) and ATA Polytechnic Bauchi (BH9)]. The values of sample GW1, GW3, GW6, GW7, GW8 and BH9 exceed the NIS [21] set limits. This might be due collection time and when compared it was within the maximum permissible limit of world Health Organisation [22]. The ranges for electrical conductivity (EC) were 310-1210 µs/cm [lowest in ATA polytechnic Bauchi (BH9) and highest in Wuntin Dada (GW3)]. The high electrical conductivity values of samples GW2 and GW3 exceed the NIS [21] set limits. The high values of EC might be due to high concentration of dissolved ions, which could cause osmotic effect, specific ion toxicity and soil particle dispersion [23]. The turbidity values were in the range 1-162 NTU [lowest in Guru (GW4) Bello Kaliel (GW6), ATA Polytechnic Bauchi (BH9 and GW10). The high values of samples GW1, GW7 and GW8 exceed the NIS [21] set limits. This may be attributed to soil type and the routine fetching of water in the wells by the inhabitants thus inducing turbidity. Turbidity reduces transparency of water [24]. The total dissolved solids (TDS) values were in the range 155-600 mg/L [lowest in ATA Polytechnic Bauchi (BH9) and highest in Wuntin Dada (GW3)]. The high value of sample GW3 exceeds the NIS [21] set limits. Values of TDS have direct relationship with the values of electrical conductivity [25]. High values of TDS might be due to the fact that the samples were collected in dry season, soil metals are highly concentrated as a result of evaporation. High TDS values can cause ion toxicity and osmotic effect [23]. The total hardness of the samples were in the range of 125-360 mg/L [lowest in Sabon Kaura (GW8) and highest in Wuntin Dada (GW3)]. The high values of GW1, GW2, GW3, GW4, GW5, GW6, GW7 and GW10 exceed the NIS [21] set limits. The highest level of calcium bicarbonate and hardness and the high value of total hardness might be attributed to Ca^{2+}, Mg^{2+}, CO_3^{-} and HCO_3^{-}. These cause waste of soap and formation of scales in boilers and overheating of boilers [5, 25].

The lowest and highest levels of elements detected ranged from between 0.001mg/L for Lead and 282.5 mg/L for Chloride. The highest levels of total trace heavy metal ions were found in the water samples from Rafin Tambari (GW7) as can be seen in Table1. In this station, Cu, Zn and Pb concentrations were found to be 0.42mg/L, 0.82mg/L and 0.00mg/L which is below the permissible levels of NIS

[21] while iron 4.150mg/L which is above the permitted levels of NIS [21].

The lowest level of total heavy metal contents in the water samples from the study area was found in the Bello Kaliel station (GW6). In this station, Fe, Cu, Zn and Pb concentrations were found to be 0.00mg/L respectively which is below the maximum permissible limits of NIS [21].

Iron concentrations in the water samples were in the range of 0.00-4.150mg/L. the lowest and highest values were in Bello Kaliel (GW6) and Rafin Tambari (GW7). The high values of samples GW1, GW2, GW4, GW5, GW7 and GW8 exceed the NIS [21] set limits. The high values might be due to the dissolution of iron present in the environment or due to the soil infiltration of Fe^{2+}; it has gotten little concern as health hazard [23].

Copper concentrations in the water samples were in the range of 0.00-0.54mg/L. The lowest and highest values were in Bello Kaliel (GW6) and Wuntin Dada (GW3). The values of the concentrations of copper in all the stations were below the maximum permissible limit of NIS [21].

Zinc concentrations in the water samples were in the range of 0.00-1.043mg/L. The lowest and highest values were in Guru (GW4), Kyaure (GW5), Bello Kaliel (GW6), ATA Polytechnic Bauchi (BH9) and Wuntin Dada (GW3). The values of the concentrations of zinc in all the stations were below the maximum permissible limit of NIS [21].

Lead concentrations in the water samples were in the range of 0.00-0.001mg/L. The lowest in Tsohon Kampani (GW1), Lafiyari (GW2), Wuntin Dada (GW3), Guru (GW4), Bello Kaliel (GW6), Rafin Tambari (GW7), Sabon Kaura (GW8), ATA Polytechnic Bauchi (BH9 and GW10) and Kyaure (GW5). Nine samples concentrations were below while the sample in Kyaure (GW5) is within the permissible limit of NIS [21].

Chromium concentrations in the water samples were in the range of 0.00-0.031mg/L. the lowest in Tsohon Kampani (GW1), Guru (GW4), Bello Kaliel (GW6), Rafin Tambari (GW7), Sabon Kaura (GW8), ATA Polytechnic Bauchi (BH9) and the highest in ATA Polytechnic Bauchi (GW10). The high values in GW3, GW5, and GW10 exceeds While GW1, GW2, GW4, GW6, GW7, GW8, BH9 are below the NIS [21] set limits.

Fluoride concentrations in the water samples were in the range of 0.02-1.32m/L. The lowest in Rafin Tambari (GW7) and the highest in Lafiyari (GW2). The high concentration value in Lafiyari (GW2) exceeds, while the concentration is below the maximum permissible limit of NIS [21] in all the remaining nine (9) stations.

Nitrate concentrations in the water samples were in the range of 20.41-189mg/L. The lowest in ATA Polytechnic (BH9) and the highest in Lafiyari (GW2). The concentrations of nitrate are below the maximum permissible limit (MPL) in ATA Polytechnic (BH9) while it exceeds the MPL in all the remaining nine (9) stations. The high value of NO_3^- might be attributed to nitrogenous waste and fertilizers. Nitrate in drinking water at level above 45mg/L is a health risk for infant less than six (6) months old; it causes blue baby syndrome and eutophication [25].

Sulphate concentrations in the water samples were in the range 49-227mg/L. The lowest in ATA Polytechnic (BH9) and the highest in Wuntin Dada (GW3). The high values in GW1, GW2, GW3, GW4, GW5, and GW10 exceeds, while GW6, GW7, GW8 and BH9 are below the maximum permissible of NIS [21]. High value of SO_4^{2-} might be attributed to the dissolution of SO_2. SO_2 from incessant burning of old vehicle tyres which dissolved in rain and falls down into the water bodies as acid rain and might cause dehydration and gastro intestinal irritation [22].

Chloride concentrations in the water samples were in the range of 47.5-282.5mg/L. The lowest in Sabon Kaura (GW8), ATA Polytechnic Bauchi (BH9) and the highest in Wuntin Dada (GW3). The values in GW1, GW2, GW4, GW5, GW6, GW7, GW8, BH9 and GW10 are below while that in Wuntin Dada (GW3) is above the maximum permissible limit of NIS [21].

Carbonate concentrations in the water samples were in the range of 58.8-192mg/L. The lowest in Sabon Kaura (GW8) and highest in Wuntin Dada (GW3).

Potassium concentration in the water samples in the range of 48.9-252mg/L. The lowest in Sabon Kaura (GW8) and highest in Wuntin Dada (GW3).

Sodium concentration in the water samples were in the range of 31.32-186.45mg/L. The lowest in ATA Polytechnic Bauchi (BH9) and highest in Wuntin Dada (GW3). Salinity as NaCl concentration in water samples were in the range of 50.34-301.5mg/L. The lowest in ATA Polytechnic Bauchi (BH9) and highest in Wuntin Dada (GW3).

Total coliform in the water samples were in the range of 84-905 cfu/100ml. The lowest in Bello Kaliel (GW6) and the highest in Kyaure (GW5). All the ten (10) samples total coliform are above the maximum permissible limit of NIS [21]. These high values might be attributed to proximity of dump sites, gutters and pit latrine to water bodies especially wells in which gradual infiltration occur thereby contaminating the water. This might lead to severe dysentery and other water borne diseases.

Faecal coliform in the water samples were in the range 42-845 cfu/100ml. The lowest in Lafiyari (GW2) and the highest in Kyaure (GW5). All the ten (10) samples total coliform are above the maximum permissible limit of NIS [21]. These high values might be attributed to proximity of the water bodies to gutter, dumpsites and pit latrines. This may lead to severe water borne diseases.

4. Conclusion

The results of the physico-chemical and microbial analyses of the water samples show that the highest turbidity is in Lafiyari (GW2), temperature is in Bello Kaliel (GW6). Electrical conductivity (EC), Total Dissolved Solids (TDS) and total hardness have their highest concentration value in Wuntin Dada (GW3), which all exceed the maximum permissible limit of NIS [21].

Calcium and magnesium have their highest concentrations at Wuntin Dada (GW3) and Kyaure (GW5) respectively which exceed the maximum permissible limit of NIS [21].

The highest value of the concentration of Fe is in Rafin Tambari (GW7), which exceed the NIS [21] set limits.The Cu, Zn and Pb concentrations were less than acceptable limits, while the sample in Kyaure (GW5) was at the normal NIS range [21]. F^- and NO^{3-} shows highest concentrations value in Lafiyari (GW2) respectively while SO_4^{2-} and Cl^- have their highest concentrations value in Wuntin Dada

Table 1: Combined Results of Physical, Chemical and Microbiological Parameters of Analyzed Water Samples in Parts of Bauchi Metropolis and Environs

S/No	Parameters	Water Samples										NIS NSDWQ*MPL
		GW1	GW2	GW3	GW4	GW5	GW6	GW7	GW8	BH9	GW10	
1	Longitude (decimal degrees)	9.754944	9.751806	9.76875	9.78975	9.784639	9.776694	9.772639	9.783139	9.770111	9.768361	
2	Latitude (decimal degrees)	10.312444	10.325556	10.315528	10.324083	10.308972	10.310028	10.300028	10.293139	10.307722	10.308083	
3	Elevation (m)	649	636	630	623	627	629	626	618	622	629	
4	Water Source	Well	Well	Well	Well	Well	Well	Well	Well	Borehole	Well	
5	Depth of Well/Pond/Borehole (m)	7.50	6.70	10.40	9.60	5.30	6.90	6.80	9.30		6.00	
6	Static Water Level (m)	7.30	5.56	10.15	9.52	5.16	6.46	6.70	9.10		4.60	
7	Temperature(^{0}c)	29.0	27.0	29.0	27.4	27.0	30.0	29.0	29.0	30.0	28.0	-
8	pH	7.1	6.7	7.3	7.7	7.5	7.0	7.2	7.3	8.2	7.2	6.5-8.5
9	Turbidity(NTU)	26	162	4	1	2	1	57	31	1	1	5
10	Electrical Conductivity(µS/cm)	560	1010	1210	670	700	510	430	320	310	610	1000
11	TDS(mg/l)	280	510	600	340	350	255	215	160	155	350	500
12	Total Hardness(as $CaCO_3$) mg/l	200	310	360	260	290	195	170	125	130	160	150
13	Bicarbonate, HCO_3^-(mg/l)	187	280	320	243	212	145	143	98	120	148	-
14	Calcium,Ca^{2+} (mg/l)	76	122	132	86	90	76	60	48	50	58	75
15	Magnesium, Mg^{2+} (mg/l)	2.44	1.44	7.33	10.9	15.87	1.44	4.88	1.45	1.43	4.88	0.20
16	Total Iron, Fe^{2+}(mg/l)	2.475	2.10	0.10	0.375	0.35	0.00	4.150	2.13	0.075	0.200	0.3
17	Copper, Cu^{2+}(mg/l)	0.431	0.61	0.54	0.01	0.12	0.00	0.42	0.00	0.174	0.00	1.0
18	Fluoride, F^-(mg/l)	0.28	1.32	0.17	0.681	0.610	0.520	0.02	0.621	0.471	0.412	1.0
19	Zinc, Zn^{2+}(mg/l)	1.04	0.761	1.043	0.00	0.00	0.00	0.82	0.651	0.00	0.712	3
20	Nitrate, NO_3^-(mg/l)	78.08	189.0	76.0	98.4	95.0	79.01	76.4	78.5	20.41	96.41	50
21	Nitrite, NO_2^-(mg/l)	0.5722	1.637	1.645	0.264	0.370	0.132	0.495	0.145	0.027	0.706	0.2
22	Lead, Pb^{2+}(mg/l)	0.00	0.00	0.00	0.00	0.001	0.00	0.00	0.00	0.00	0.00	0.001
23	Sulphate, SO_4^{-2}(mg/l)	178	201.0	227	109	165	98.0	75	52	49	143	100
24	Chloride, Cl^-(mg/l)	122.5	242.4	282.5	120	122.5	87.47	74.97	47.5	47.5	97.45	250
25	Chromium, Cr^{6+}(mg/l)	0.00	0.002	0.016	0.00	0.020	0.00	0.00	0.00	0.00	0.031	0.05
26	Carbonate, CO_3^-(mg/l)	112.2	168	192	145.8	127.2	87	85.8	58.8	72	88.8	-
27	Potassium, K^+ (mg/l)	59.31	221	252	49.53	105	122.5	103	48.9	50.5	203	-
28	Salinity as NaCl (mg/l)	119.2	237.4	301.5	127.2	129.9	92.72	79.47	50.35	50.34	103.3	-
29	Sodium, Na^+(mg/l)	74.25	103.26	186.45	79.2	80.85	57.7	49.48	31.35	31.32	64.31	-
30	Total Coli form (cfu/100ml)	214	121	134	150	905	84	152	210	251	301	0
31	Faecal Coli form (cfu/100ml)	75	42	70	49	845	43	114	152	101	95	0

NSDWQ - National Standard for Drinking Water Quality; NIS – Nigerian Industrial Standard, 2007; *MPL – Maximum Permissible limits

(GW3) respectively, this is above the maximum acceptable limits of NIS [21]. Total coliform and faecal coliform have their highest values in Kyaure (GW5) and all the values of the ten (10) samples for these parameters are above the maximum permissible limit of NIS [21]. These high values may be due to proximity of the water bodies especially wells to dumpsites, gutters and pit latrines. This may lead to severe water borne diseases.

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